RE-ORDER NO. 62-668
950454

0370262

BALL BROTHERS RESEARCH CORPORATION

BOULDER, COLORADO

FINAL REPORT

OF

JPL STUDY CONTRACT PLD-01

"VIDEO MODULATION TEST FACILITY STUDY"

title Final Report

(NASA Contract NAS7-100; JPL Contract PLD-01)

Index JPL-PLD-01

(NASA CR-53739)

PREPARED

Glen R. Southworth
Research Engineer [1960] 62p refs

APPROVED

R. G. Salaman, Chief
Digital Communications Dept.
D. S. Stacey
Technical Director

This work was performed for the Jet Propulsion Laboratory, California Institute of Technology, sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Section 1

INTRODUCTION

1.1 Introduction

The purpose of this study is to analyze the parameters relevant to the design and construction of a high-quality television test facility for research in modulation techniques for space communications. Primary objectives are to obtain a slow scan television image with bandwidths on the order of 10 kc but with picture resolution as high as is practical with the current state of the art. Further, that the equipment shall be convenient to both operate and maintain but shall be flexible enough that advanced research programs may be readily implemented. In addition the system should be able to provide means for convenient and accurate analysis of picture parameters from the standpoint of reproducibility and scientific investigation.

The accomplishment of the above goals by use of conventional techniques has been considered difficult and expensive. Consequently, this study program has been based around a concept described by Altes and Reed[1] and further developed during the past year by BBRC. Specific areas of investigation in this report refer to the final performance parameters of equipment which may be reasonably expected through useage of this technique and in system features and configurations which will anticipate future needs in modulation studies.

A simplified block diagram of the proposed test facility is shown in Figure one. A versatile synchronizing generator provides basic timing information for all units as well as several test signals. Conversion from optical energy

[1] S. K. Altes and H. E. Reed "Slow Scan Adapter for Conventional TV Signals," ELECTRONICS, June 1, 1957

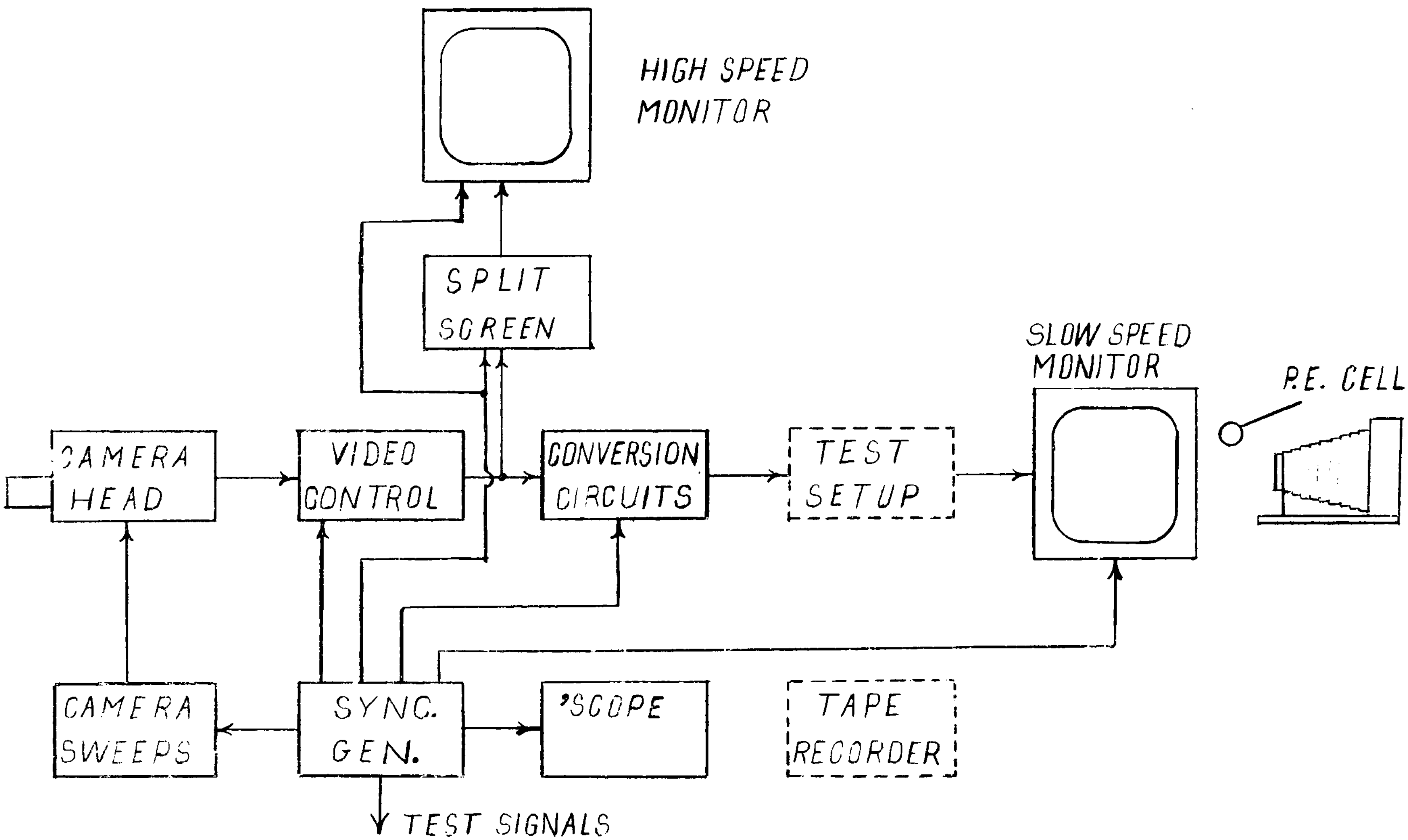


FIG 1. TEST FACILITY SYSTEM BLOCK DIAGRAM

to wideband television signals is accomplished in a high resolution camera head, with subsequent video data operations performed in the associated control unit. Real time observation of system performance may be obtained at this point from the screen of a conventional monitor with a split screen unit employed to balance two sets of optical input data.

Electronic conversion to a narrow band slow scan signal occurs after the output of the high speed camera system with the resulting signal being used as a source for modulation-demodulation experiments or being applied to an analog-to digital converter for subsequent computer analysis. Provision is also made for tape recording of these signals for future playback while a special slow scan monitor of very high resolution capabilities is employed as a light source for the final reconstruction of images on photographic film.

Section 2

2.1 Camera Tube

2.1.1 Resolution Capabilities

The recently introduced Type 8051, 1-1/2 inch vidicon transducer, appears to be ideally suited to the system discussed. For normal operation, limiting resolution is of the order of 1,200 television lines. In comparison with other available television pickup tubes, the Type 8051 is capable of 60 per cent response at 400 television lines as compared with the 30 per cent response at 400 lines for the 1 inch vidicon, such as the type 7038 and 26 per cent at 400 lines for the type 5820 image orthicon. The only serious competitor in terms of resolution capabilities is the recently introduced 4-1/2 inch image orthicon which has approximately the same resolution performance as the Type 8051; however, this tube is much bulkier, more complicated and expensive, difficult to set up and operate, and has limited life as well as being quite susceptible to damage.

General Precision Laboratories has been successful in obtaining improved resolution from standard 1 inch vidicon by means of increasing the magnetic focus field surrounding the vidicon.[2] It is anticipated that this technique might improve the characteristics of the Type 8051 to the point of achieving 30 per cent amplitude response at 1,000 lines. Response curves for the 8051 are shown in Figure 2, and it will be noted that approximately 12 db of aperture correction would be sufficient to give approximately 100 per cent response at 800 TV lines with the normally operated tube.

[2] L. L. Pourciau, M. Altman, and C. A. Washburn, "A High Resolution Television System," Journal of the SMPTE, Volume 69, February, 1960

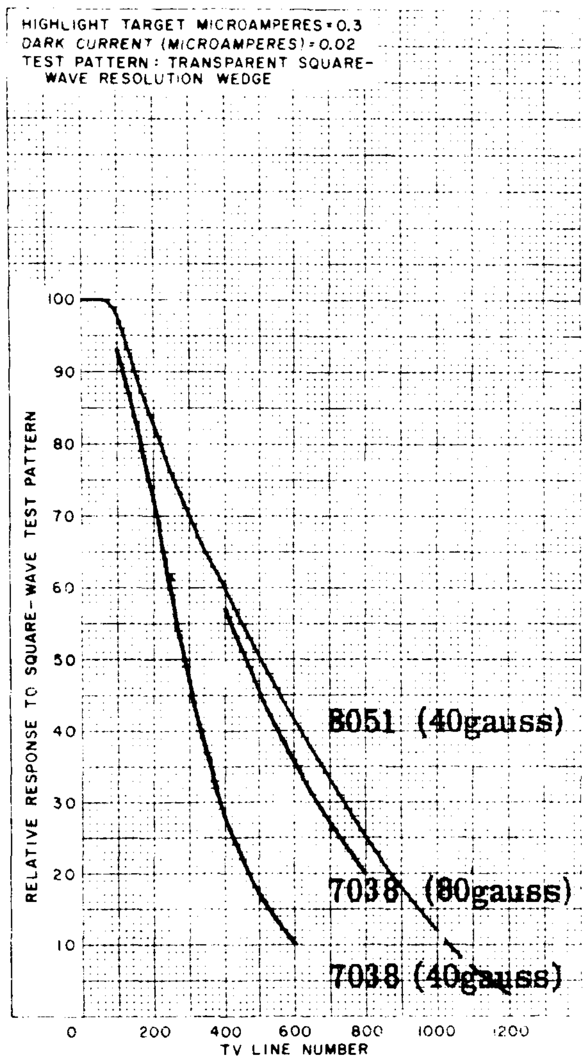


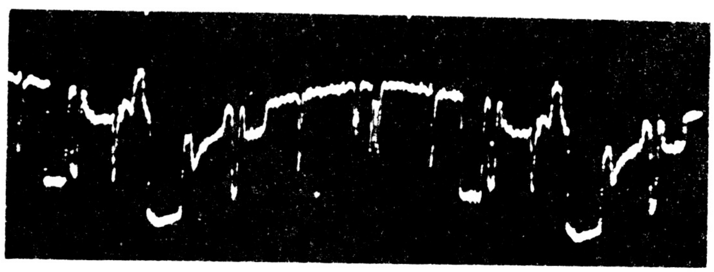
FIG 2, 8051 Resolution Chart

2.1.2 Noise

It is generally considered that the vidicon tube is capable of one of the best signal-to-noise ratio characteristics of any of the TV input devices and, although not as sensitive as the image orthicon is capable of significantly better dynamic range. Most of the noise appearing in the video output signal originates in the preamplifier and will occur in the upper part of the video spectrum due to the necessity of equalization to compensate for high frequency losses due to the vidicon output capacitance and the pre-amplifier input capacitance.

In a sampling type of slow scan TV system high frequency noise is of considerable significance inasmuch as the sampling process will convert it to the narrow band equivalent. In order to obtain actual data relating to practicable signal-to-noise ratios of this type of system tests were run using slow scan prototype sampling equipment in conjunction with a standard broadcast TV camera chain the RCA TK21-C, which employs a low noise cascode, video pre-amplifier. The overall bandwidth of the camera chain was 8 mc, and the conversion efficiency of the sampling aperture was such that the output of the sample and hold circuitry was down 3 db at 5 mc. The results in terms of peak-to-peak noise components compared to peak-to-peak video components are shown in Figure 3 The aperture correction indicated refers only to the wide band circuitry in the TK21 which was set to provide approximately 12 db of high frequency boost at 4 mc. Peak-to-peak noise ratios to peak-to-peak video of nearly 50 to 1 were obtained under optimum conditions, without aperture correction when examining the slow scan output. It is more conventional in TV practice to compare RMS noise voltages to p-p signal voltages and this was done by means of measurements with a Hazeltine RMS volt meter. Under these conditions a ratio of approximately 40 db was

a. Slow Scan Signal Derived from Standard TV Camera Chain with Normal High Frequency Response



b. Conditions As Above But with 12 db of Aperture Correction in the High Speed Camera Chain

FIG 3, SIGNAL-TO-NOISE RATIOS IN SLOW SCAN SIGNAL obtainable with normal vidicon setup without aperture correction with approximately 6 db of the noise being produced by a 120 cycle component originating in the camera chain.

It should be noted that usual TV practice is to weight signal-to-noise ratios in such a manner as to attenuate high frequency components on the theory that these are less objectionable to the viewer. Although this is quite possibly valid for entertainment type TV, there is a distinct question whether this weighting should be used for single frame TV reproduction intended for scientific purposes and also whether it is a valid indication of quality when digital modulation techniques are used and quantization noise is a factor in reproduction.

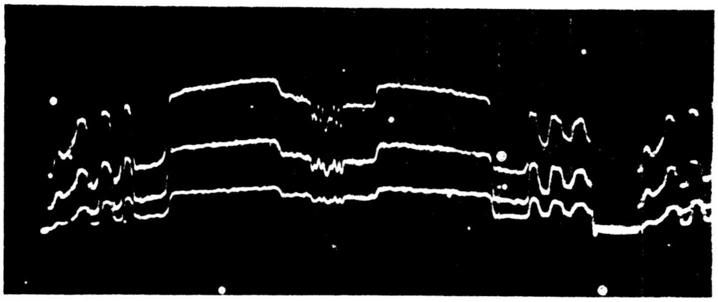
Comparing the performance data of the 1-1/2 inch vidicon to that of the 1 inch vidicon used in the preceding tests, it will be noted that the beam current allowable with the 1-1/2 inch unit is nearly twice of that of the 1 inch tube. However, the target capacitance is appreciably greater than that of the 1 inch tube with the result that correspondingly more high frequency equalization is required. A readily obtainable signal-to-noise ratio of 40 db is indicated however, with marked improvement in resolution when using a 1-1/2 inch tube.

2.1.3 Color Response

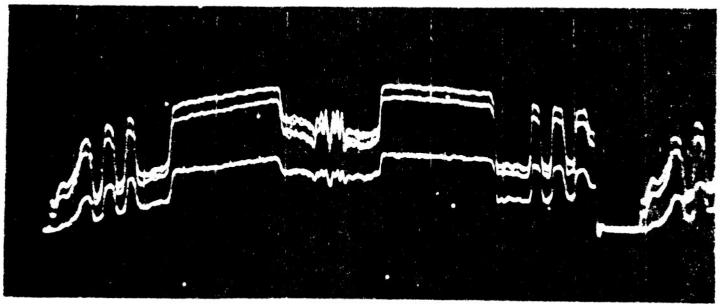
The Type 8051 vidicon is normally supplied with a target which has an S-18 response, other target materials being available on special order from RCA. A substantial increase in sensitivity occurs between the red and blue portion of the visible spectrum and is very desirable when low temperature light sources, such as standard incandescent lamps are used in illuminating the camera subject. A number of experiments have been conducted during the course of this study program using the Wratten tri-color separation filters, Types 25, 47B, and 58 in conjunction with the GEC Type 7325 vidicon which also has an S-18 spectral response characteristic. The scope traces in Figure 4 show superimposed the output of the slow scan system when the three separate red, green, and blue filters are interposed between the camera lens and the visual subject, with the illuminating source being normal tungsten lamps. The combination of low temperature light and different transmittance of the filters causes the red output to greatly predominate, the green being down to approximately 60 per cent, and the blue producing only 25 per cent output in an almost direct reversal of the slope of the camera tube response. Figure 4b shows the same experiment repeated with a higher temperature light source, in this case a normal fluorescent light fixture. Improvements in color balance may also be obtained by use of color filters in front of the camera lens or between the light source and the subject.

If it is desired to use the system to obtain colored photographic reproductions it is possible to take three separate exposures of the same color negative. The first exposure is with a red filter between the TV camera lens and the subject and a second red filter between the slow scan monitor and the photographic camera lens. This process is repeated with green and blue filters to obtain a composite exposure, which is subsequently processed and printed in normal fashion.

Reasonably good results may be obtained with the above technique by using a standard P4 "white" kinescope phosphor and KODACOLOR negative film, an example being shown in Figure 5. This photograph was taken from a standard TV screen, and due to the low sensitivity of the film required an exposure of several seconds for each color. For single scan pictures a very strong light output from the screen would be required, with attendant problems of focus



a. S-18 Vidicon Response to Low Kelvin Tungsten Light Through Wratten Filters. Top Trace is Red, Middle Trace is Green, and Bottom Trace is Blue.



b. S-18 Vidicon Response to Medium Temperature Fluorescent Light Source. Top Trace is Red, Middle Trace is Green, and Bottom Trace is Blue.

FIG 4, VARIATION IN VIDICON ELECTRICAL OUTPUT WITH COLOR TEMPERATURE OF SUBJECT ILLUMINATION

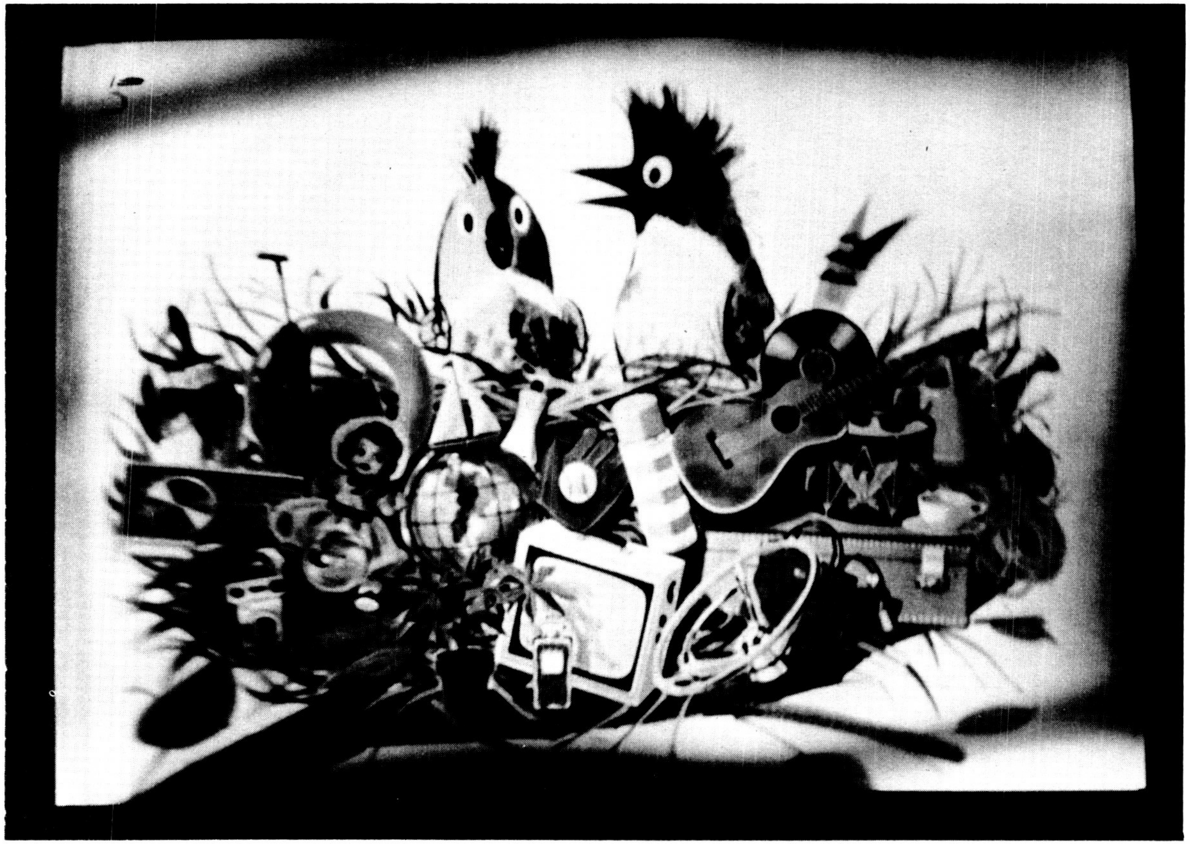


FIG 5, Kodacolor Reproduction from P4 CRT Screen
Using Wratten Type 25, 58, and 47B Filters

halation effects and possible phosphor burn. A large improvement in film sensitivity may be obtained through EKTACOLOR S or EKTACOLOR L, which are approximately five times as fast as the KODACOLOR negative, or it is possible to increase speed by a factor of 10 compared to KODACOLOR, by using High Speed EKTACHROME, developing it as a negative and printing on type C paper.

It is desirable to use a "color blind" phosphor in the slow scan monitor for several reasons, including improved resolution, freedom from "grain" and short persistence, which allows convenient P.E. cell monitoring. Color reproductions may be obtained in this case by inserting filters only between the TV camera and subject and exposing three separate black and white negatives to the image on the face of the monitor tube. As a result each of the negatives has a grey scale rendition peculiar to the filter used in front of the camera lens at the time of exposure; and extremely high speeds, on the order of ASA 3000, may be obtained with conventional emulsions. Once developed these negatives may be used in conjunction with a photographic technique known as the Dye Transfer Process to reconstruct a color picture. Unfortunately this method is both cumbersome and expensive with the result that an alternate approach was attempted during this study, that of sequentially projecting each of the three negatives through appropriate color filters on to standard color enlarging paper, taking care to properly register each exposure. Results were still inconclusive at the time that this report was written, although it is hoped that this technique will prove workable.

Regardless of the techniques used to obtain color reproduction it should be noted that color balance may be equalized by either adjusting the intensity of the light source for each exposure by changing lens settings on either TV or film camera or by adjusting the electrical gain of the television system, although this would affect the signal-to-noise ratio somewhat. It would also be possible to equalize for spectral differences by changing the camera tube target potential slightly although this might change the tube gamma and shading characteristics slightly

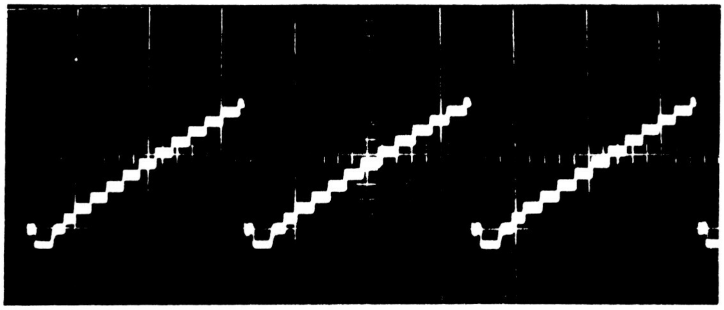
It is important to note that the photographic processing of the exposed negatives and prints obtained therefrom can radically alter color balance. As a result it is considered desirable to incorporate some form of reference for the photographer such as a known grey scale, which he may use to adjust the printing lamps in the final reproduction process. Further, it should be noted that the entire system input-output characteristics including the gammas of the input transducing vidicon, the display kinescope, film and the film processing must be taken into consideration in order to get accurate color reproduction as the end photographic result.

2.1.4 Shading Components

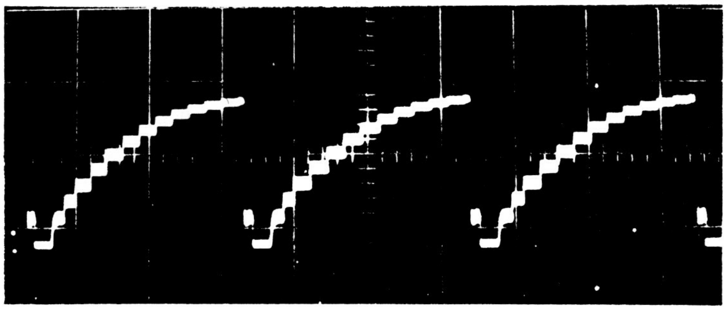
Some low frequency video components are commonly found in normal TV signals which are known as shading distortions. These can result from failure to evenly illuminate the subject field or due to problems associated with the camera tube. The vidicon is a velocity sensitive device and spurious shading components may be generated by nonlinear scanning of the vidicon target, with the result that the vidicon scanning beam must be linearly deflected in order to minimize this effect. A second shading distortion comes from beam landing errors in the striking of the electrons on the target of the vidicon tube. This usually results in a parabolic modulation with the center of the TV field being brighter than the edges of the picture. At the same time these beam landing errors tend to cause poorer focus at the edges of the picture than is obtainable in the center of the TV target. The amount of shading introduced varies with the focus coil field and may typically run from less than 10 per cent for a normal 40 Gauss field to as high as 30 per cent for an 80 Gauss focus field. This may be counteracted to a considerable degree by using parabolic focus modulation in the camera circuitry which not only produces a flatter field, but also improves edge resolution in the reproduced picture.

A further consideration is the transfer characteristic of the vidicon in terms of light input to the target and electrical output from the transducer. Typical vidicons have a transfer characteristic, or gamma, of less than unity, with the specification on the 8051 indicating a gamma of .65. This characteristic tends to compliment the curve of the normal kinescope display device which has a transfer characteristic of greater than unity, but does pose a problem when nonlinear operations are performed upon the video signal such as analog-to-digital conversion prior to the display on a kinescope tube.

Figure 6a illustrates a typical grey-scale "staircase" waveform as generated by a commercial test instrument, while Figure 6b represents the same waveform passed through a solid state compensation circuit with the output gamma adjusted to appreciably less than unity. Although this slope is commonly used to correct for kinescope light output characteristics, it is evident that considerable data compression occurs at the top of the trace which might lead to inefficient quantizing in an analog-to-digital conversion. As the camera tube, itself, also generates this type of characteristic, it may be desirable to produce the reciprocal curve in the gamma corrector before A/D encoding and use a second device to recorrect for the display kinescope characteristic after decoding of the information. Again, the type of photographic film and processing used will influence the amount of correction required.



a. Linear Staircase Signal Generated by A Commercial Test Instrument



b. Staircase Signal Passed Through Nonlinear Circuitry to Generate a Gamma of Less Than Unity

FIG 6, GAMMA CORRECTION BY MEANS OF NONLINEAR ELEMENTS

Section 3

3.1 Electronic Scan Converter

3.1.1

Conventional methods of obtaining Slow Scan TV Signals are plagued with serious operational and performance hazards. Several serious design problems are involved in the attainment of high quality signals, and setup and operation of conventional slow scan camera and monitor units is tedious and time consuming due to the lag occurring between circuit adjustments and the time that these may be appropriately monitored. As a multiplicity of system adjustments are potentially desirable in research studies, this time lag could lead to a difficult implementation of a given program particularly if any complicating factors in terms of circuit drift or component failures are involved. Similarly, it is essential that data is not masked or omitted due to system defects.

A key factor in this study is the useage of a form of electronic scan conversion wherein a low frequency analog TV signal is extracted from a wideband TV picture by means of sampling. The principle involved is the generation of narrow sliding pulses from a high speed TV system horizontal drive timing signal. This may be done as is shown in Figure 7 with the result being a series of narrow samples forming a virtual vertical line which may be electronically positioned at any place on the TV raster, as illustrated by Figure 8. The original television picture signal may then be combined in such manner that these pulses are changed in amplitude according to the relative brightness of the TV image at the point at which they occur. Following this it is a relatively simple task to cause the apparent vertical row to move slowly across the TV raster sampling the entire picture.

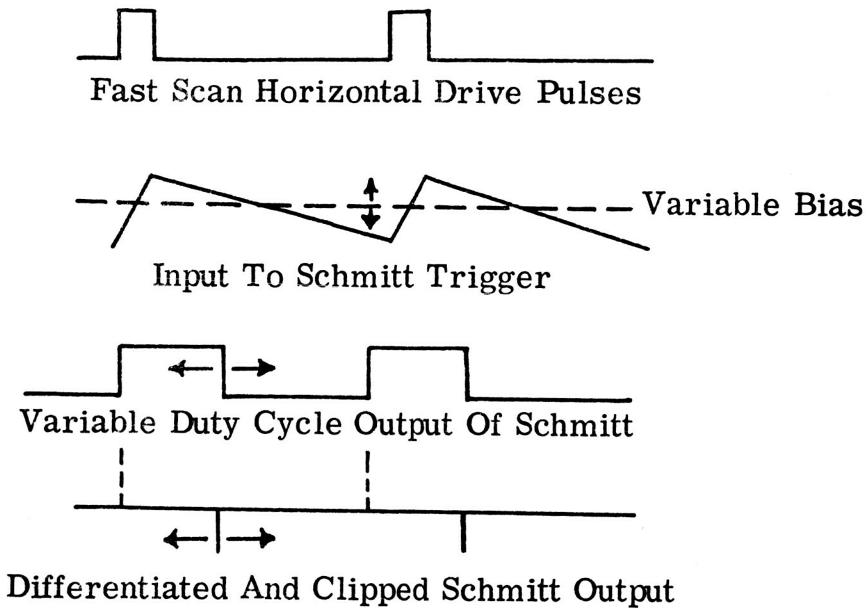


FIG 7

Generation Of Sliding Sampling Pulses
For Electronic Scan Conversion

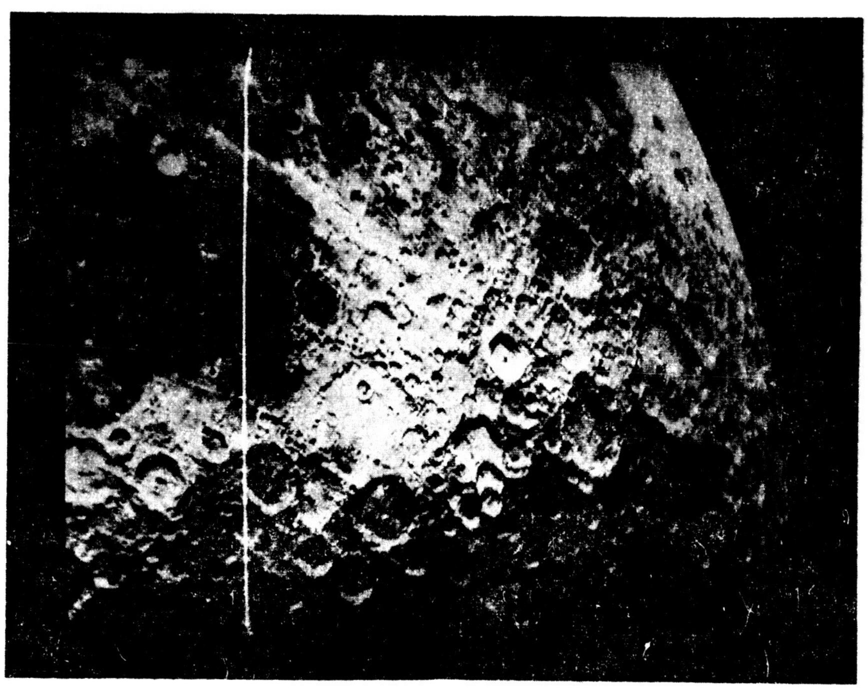


FIG 8

Single Row Of Sampling Pulses Superimposed Upon
A Conventional TV Raster

Although the original TV picture might have contained 1000 or more elements per TV line, the sampling pulse only recognizes one of these elements, and when "stretched" by means of additional circuitry represents a very large reduction in bandwidth. A change in scanning axis occurs during the conversion process, and the low speed line rate sweeps the picture from top to bottom while the low speed frame is swept from left to right. An unique advantage of this is that unusually high resolution pictures may now be obtained by first using aperture correction in the conventional video channel to improve horizontal axis detail and once again in the slow speed channel to increase vertical axis detail. Alternately for experimental purposes the effective resolution on either or both axes may be reduced by means of electrical filters or a change in scanning rate.

A significant aspect of the sampling type of bandwidth reduction is that the "readout" is nondestructive and the sampling line may be "stopped" at any point of interest in the picture, continually rescanning the same area for analysis of signal structure in either the original or reconstructed video with a marker, as shown in Figure 9a indicating the point of signal origin. Picture quality on the other axis may be analyzed, as shown in Figure 10, by using conventional oscilloscope techniques employing a delayed triggered sweep and wide band examination of the original video signal.

Virtually all operations and adjustments relating to the initial creation of the TV image are carried on in real time and may be easily evaluated on a conventional TV monitor. The electronic bandwidth reduction technique is of extreme simplicity compared to systems involving the use of special storage tubes and introduces far less degradation in the signal. Operationally, very few additional controls need be involved and relatively simple circuitry can be used to obtain the slow scan readout.

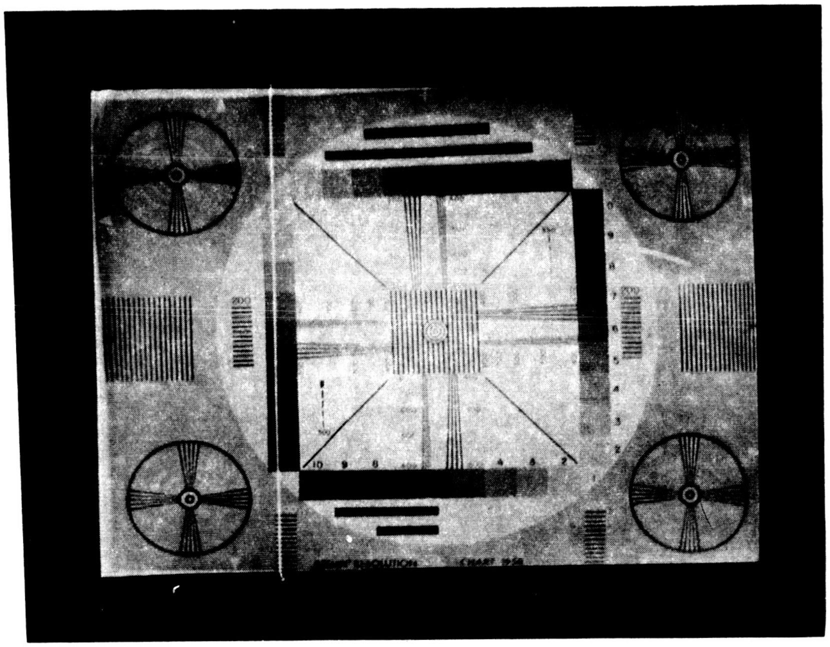


FIG 9a, Television Image with Vertical
Marker Superimposed

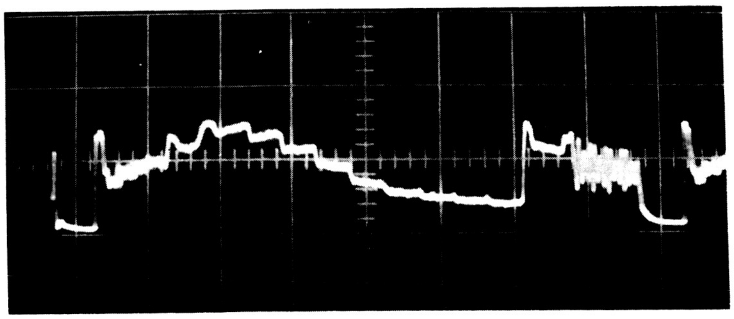


FIG 9b, Oscilloscope Trace of Single Line of
Vertical Information as Indicated in 9a

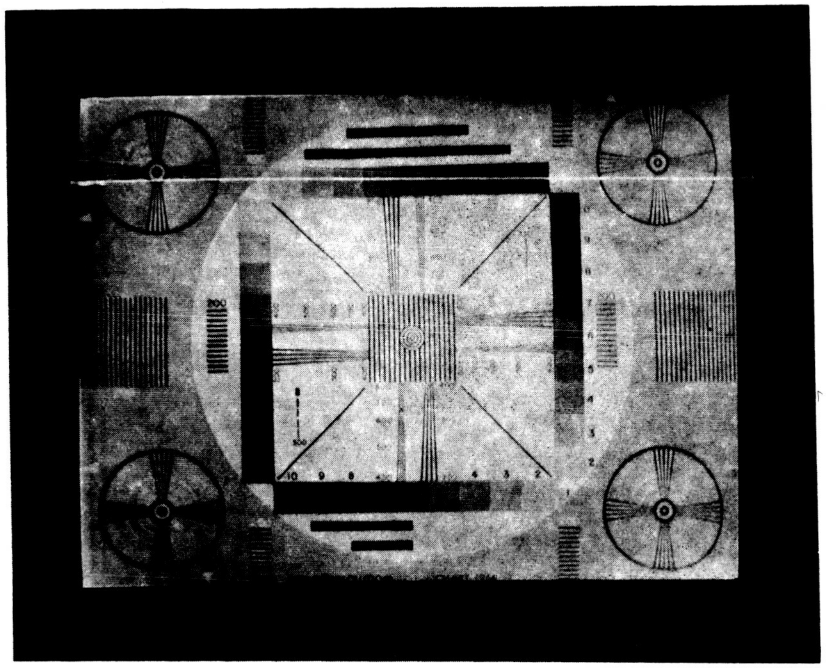


FIG 10a, Television Image with Horizontal
Marker Superimposed

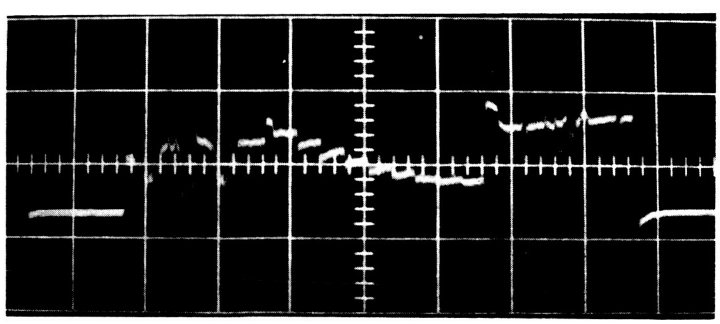


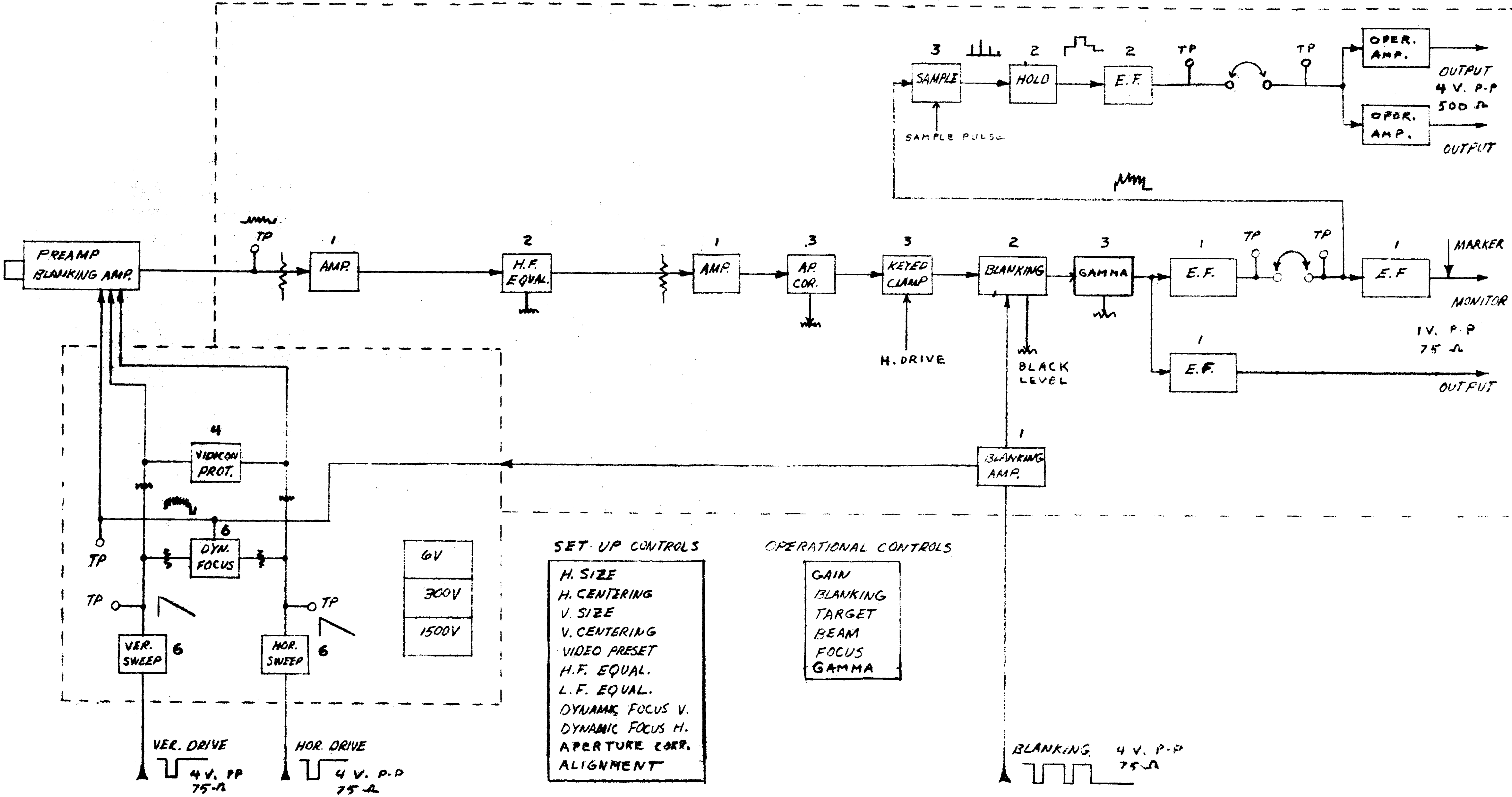
FIG 10b, Oscilloscope Trace of Single Line of
Horizontal Information as Indicated in 10a

The quality of the end reproduction in the slow scan signal is determined initially by the operating characteristics of the high speed camera. Advantage may be taken here of the considerable body of experience obtained in the past few decades in conventional camera design, and an outline of various circuit elements and features considered worthwhile follows.

Figure 11 shows a block diagram of the basic TV camera which is divided roughly into three sections, the first being the camera head which contains the vidicon tube and its associated magnetic deflection coils, focus coils, and alignment coils plus a video preamplifier and the optics associated with the tube. The second subsection contains the necessary sweep circuitry to drive the beam deflection in the tube, dynamic focus circuitry to improve flatness of the TV field and improve corner resolution capabilities, protective circuitry to cut off beam current in event of sweep failure (which would otherwise result in damage to the sensitive target of the vidicon), and finally the appropriate voltages for application to the vidicon tube elements.

The third section of the camera is the video amplification circuitry which takes the output of the camera head preamplifier and processes it first into an appropriate real time TV signal by means of amplification, high frequency equalization, aperture correction (which may be used to compensate for the finite size of the vidicon scanning beam), a keyed clamp to reduce possible hum or low frequency distortions occurring previously in the video circuitry, and a blanking amplifier for the purpose of establishing the correct black level in the output signal. Also indicated is a gamma corrector for purpose of obtaining a more linear output signal in order to compensate for the .65 gamma characteristic of the vidicon. Following this, an emitter follower is used to reduce the video signal impedance to the order of 75 ohms, and provision is made for the insertion of filters or supplementary signal processing equipment in the

FIG 11


PREAMP BLANKING AMP.
TP
AMP.
H.F. EQUAL.
AMP.
AP. COR.
KEYED CLAMP
H. DRIVE
BLANKING
BLACK LEVEL
GAMMA
E.F.
E.F
MARKER
MONITOR
1V. P-P 75 Ω
OUTPUT
SAMPLE
SAMPLE PULSE
HOLD
OPER. AMP.
OUTPUT 4 V. P-P 500 Ω
BLANKING AMP.
VIDICON PROT.
DYN. FOCUS
VER. SWEEP
HOR. SWEEP
6V
300V
1500V
VER. DRIVE 4 V. PP 75 Ω
HOR. DRIVE 4 V. P-P 75 Ω
BLANKING 4 V. P-P 75 Ω
SET-UP CONTROLS
H. SIZE
H. CENTERING
V. SIZE
V. CENTERING
VIDEO PRESET
H.F. EQUAL.
L.F. EQUAL.
DYNAMIC FOCUS V.
DYNAMIC FOCUS H.
APERTURE CORR.
ALIGNMENT
OPERATIONAL CONTROLS
GAIN
BLANKING
TARGET
BEAM
FOCUS
GAMMA

signal path. The video is then applied to a conventional high speed TV monitor for visual observation and to the input of the electronic scan converter which consists, in essence, of sample and hold circuitry with appropriate impedance matching stages terminating in a group of operational amplifiers.

The circuitry involved in the camera lends itself well to transistorization, although tubes are anticipated in the video preamplifier section due to noise considerations. The separation of video and deflection elements tends to minimize problems of crosstalk and also makes it more convenient to provide for future modifications in either of these two areas. Due to the video frequencies involved, relatively short "point-to-point" wiring is desirable in terms of circuit stability and design economy. Particular attention must be paid in the design and layout to minimize ground loops or stray couplings between signal sources which might tend to degrade the end signal. Further, key test points as well as setup and operating controls for a device of this nature must be conveniently available to the user.

3.1.2

As indicated, the vertical deflection circuits of the high speed camera are directly driven by pulses from the synchronizing generator and can be made to operate over a range of 15 to 1 corresponding to a variation between a 100 line picture and a 1500 line picture, although some readjustment of scanning size must be made when changing standards and possibly of centering and linearity adjustments. The sweep circuits being analog devices are capable of operating continuously over the specified range but are controlled by pulses from the sync generator which will be discussed in further detail under 5.1.

3.1.3

The horizontal line sampling rate is controlled by the sync generator module and with the recommended parameters would vary from approximately 1 second for a 128 by 112 element picture to approximately 2-1/2 minutes for a 1500 by 1500 element picture. This is based upon the useage of a 15 kc horizontal sweep rate in the high speed camera. By increasing the sweep rate to 30 kc, the time required to generate a given picture would be halved, but at the same time the analog bandwidth would be doubled from approximately 7-1/2 kc to 15 kc. This probably would not be as significant as the fact that the high speed analog TV bandwidth would be increased from approximately 15 mc to 30 mc, with increased problems relating to noise and circuit stability, as well as doubling any of the problems which might arise from jitter in the sampling pulse timing.

3.1.4

Referring to Section 5, the phase advance of the sampling pulse is accomplished in the sync generator by means of digital countdown circuits generating a staircase type of ramp. It should be noted that this technique is highly desirable, not as much from slight changes in scanning axis which might occur if a sawtooth were used, but from the standpoint that the use of a counter allows an accurately known number of sampling elements to be presented in the final display. Similarly, the end voltages of the counter being accurately known make it much easier to set up the width of the slow scan sampling sweep.

3.1.5

Again referring to the sync generator, the horizontal blanking interval may be continuously variable by means of the control of the duty cycle of a multivibrator. This is also true of the vertical blanking interval, but an option is shown wherein digital blanking of 16, 32 or 64 horizontal lines may be obtained at the user's discretion.

Due to the single frame nature of the video data, a simplified sync system is used as will be described more fully under 4.1.3 relating to the slow scan monitor. In essence, any incoming data may be used to start the frame sweep signal and the leading edge of vertical drive pulses is used for the slow scan line sync signal. As only the leading edge of the drive signal is used for sync purposes, the space following this may be used for insertion of identification data inasmuch as the entire area is reblanked during the display process.

3.1.6

An investigation of the literature indicated that the Butterworth filter was probably the most commonly used in interpolation of sampled signals. If video were applied to the input of an analog-to-digital converter, such interpolation would be unnecessary due to the inherent sampling of the A/D equipment itself. However, in the analysis of analog modulation techniques it is highly desirable to have the slow scan output approximate that which would normally be expected from conventional scanning processes. The fairly rapid reduction of data amplitude with increasing frequency, as is indicated in Figure 2, simplifies the problem of interpolating the sampled signal to approximate its analog counterpart, due to the fact that the waveforms involved in reproducing TV lines above several hundred tend to be sinusoidal in character. As part of the study a three-element Butterworth filter was designed with a cutoff frequency of 7500 cycles, and an 18 db per octave rolloff. Figure 12 shows three scope patterns, the first of these being a portion of a single line of video information extracted from the high speed camera and showing the waveforms corresponding to 400 TV lines and 200 TV lines. The second scope photo shows the sampled output of the vertical axis of the same picture again showing relative response at 400 and 200 TV lines. The third trace of the series shows the result of passing the slow scan signal through the Butterworth interpolation filter and the resulting approximation to the waveforms produced

Section 4

4.1 Display

4.1.1

The use of the electronic scan conversion technique allows most of the initial setup operations, in terms of vidicon sweeps, focus, target, and beam adjustments to be made with the aid of visual examination of a high speed picture presented on a conventional monitor. A Conrac Model CQB 14 inch rack-mounted unit is recommended for this purpose, the CQB series of monitors having video response to 20 megacycles and being obtainable with any horizontal scan rate between 15 kilocycles and 37 kilocycles. The only modification anticipated on the CQB chassis would be the replacement of the original vertical sweep circuits with a special transistorized unit in order that a wide range of sweep frequencies may be accommodated.

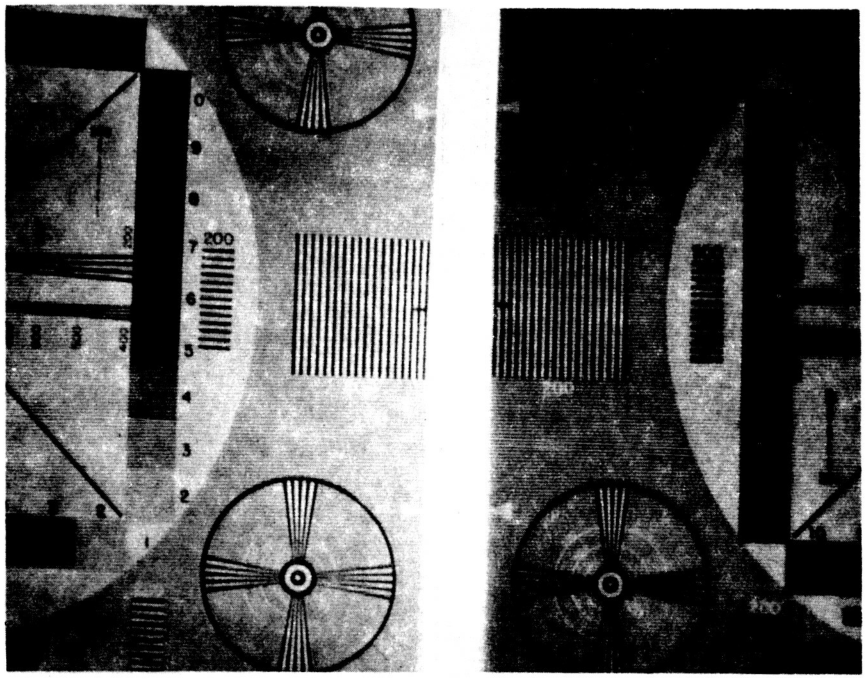
A 500 line TV picture would call for a frame frequency of approximately 30 cycles per second, and a 1500 line picture for a 10 frame per second repetition rate, both frequencies falling in an area where the human eye is quite capable of noticing flicker effects. Consequently a kinescope tube employing a long persistance phosphor such as Type P19 which is orange in color, is desirable in order to afford easier viewing. It should be noted that this represents a "grey area" in this study inasmuch as the useage of a 30 kilocycle horizontal sweep rate would allow somewhat better than 500 lines of vertical resolution to be obtained with a standard P4 white kinescope display without noticeable flicker. This would be particularly useful in the event that the high speed monitor was used as a means of subjective evaluation of modulation processes. In this particular application a split screen generator may be used to equalize brightness and contrast variations between an original hard copy subject, and reproduced copy indicating the peculiarities of the particular modulation process under investigation. A side-by-side presentation of the original and reconstructed data may then be made for the subjective analysis of the user. An example of this technique is shown in Figures 13 and 14, but it seems that a more desirable approach might be to establish accurate parameters in the attainment of photographs from the video test facilities so that side-by-side comparisons might be made between hard copy and hard copy.

4.1.2

Aside from the previously mentioned consideration, a split screen generator has definite usefulness in terms of injecting reference test signals such as a grey scale staircase. A solid state split screen generator design has been generated from previous BBRC research and has a bandwidth of approximately 30 megacycles with very good low frequency response characteristics. The unit has been designed to supply a split either on the vertical axis, the horizontal axis, or diagonally at the option of the user, and with any desired duty cycle ratio.

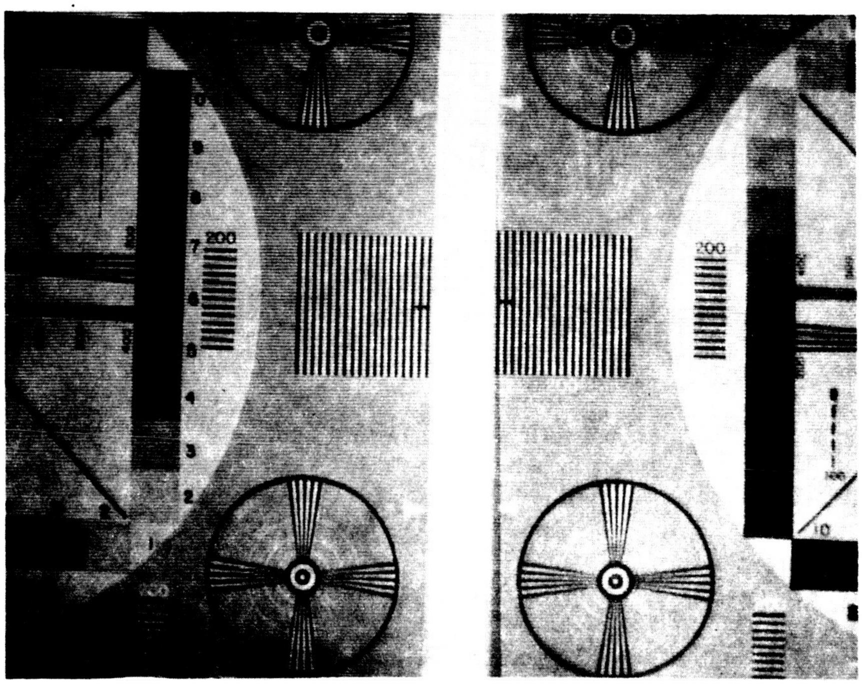
4.1.3

A special slow scan monitor is desirable for picture transcribing purposes, although a means of accomplishing this purpose with a conventional TV monitor will be described in the following paragraphs. The block diagram of a recommended circuit configuration is shown in Figure 15 and is capable of operating in three separate modes. The first of these is direct drive by the system synchronizing generator. In this case, the line frequency sawtooth is derived from the synchronizing generator vertical drive output pulse, and the frame deflection signal comes from the staircase output of the low frequency



OPTICALLY UNBALANCED TEST PATTERNS

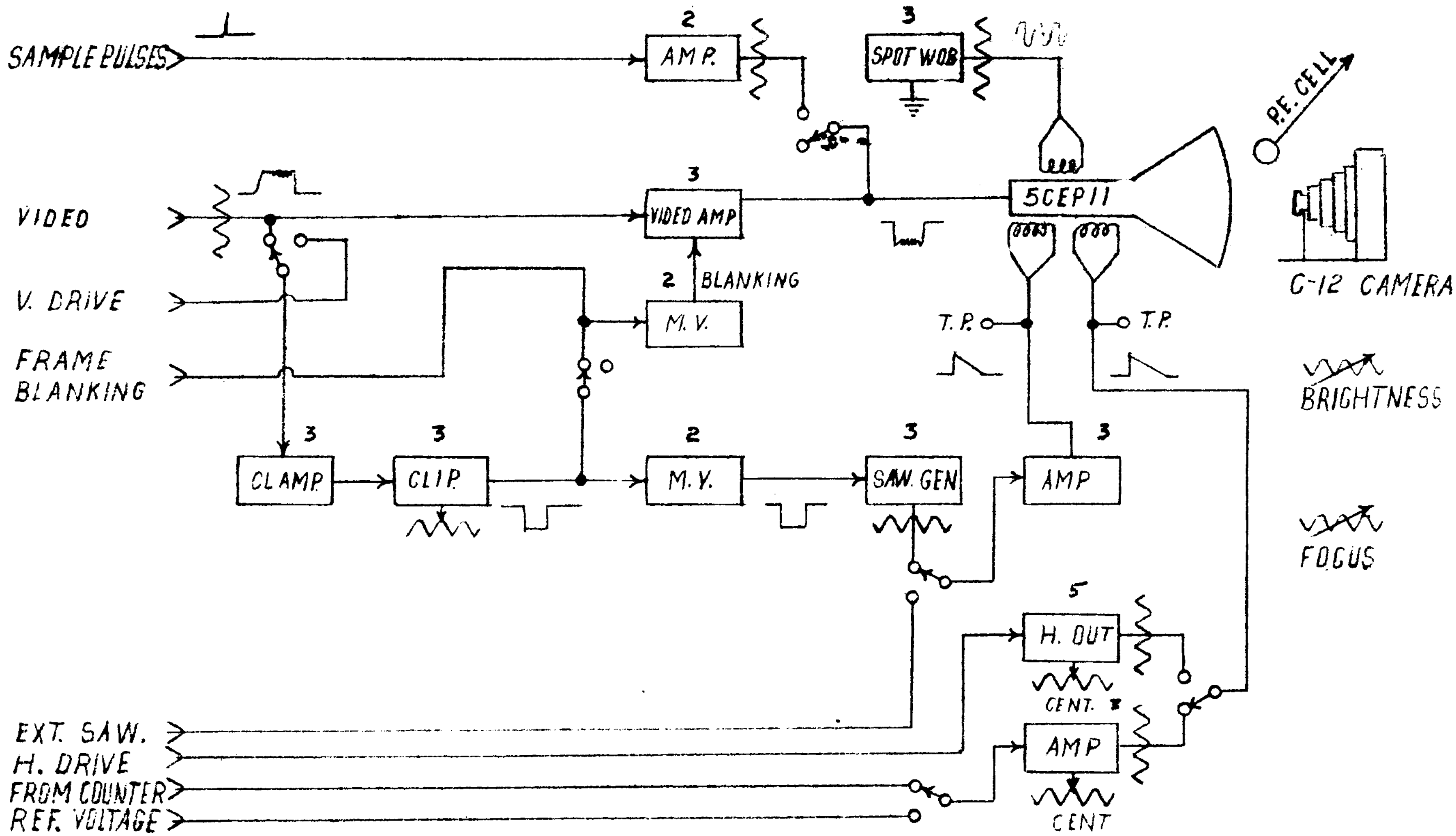
Fig. 13



SIGNAL OF FIGURE 13 BALANCED BY SPLIT SCREEN GENERATOR

Fig. 14

FIG 15, SLOW SCAN MONITOR



counter in the synchronizing generator. The circuitry is so arranged that no light output occurs from the face of the kinescope tube until the actual frame deflection signal occurs, thus preventing a continuous stationary bright line which might fog the photographic film in the camera or discolor the kinescope phosphor. Similarly, the same circuitry eliminates any extraneous information which may occur during the blanking period, such as the previously mentioned identification signal. Maximum output brightness from the CRT screen is obtainable in this mode of operation and relatively insensitive photographic films may be used. Provision is also made to "override" blanking in order that a stationary bright line may appear on the kinescope face for setup of scan limits and for test of the light output linearity and minimum-maximum limits by means of a photocell within the photographic camera housing.

A second mode of operation is intended to allow the system to accept tape-recorded or external video inputs. In this instance, vertical drive pulses are added resistively to the video information to provide a composite signal, similar to that used with commercial broadcast standards, with negative going synchronizing information. Slicing circuits in the slow scan monitor separate these pulses from the video information and feed them both to the blanking multivibrator and to a separate pulse multivibrator which in turn feeds a local line sawtooth generator. The pulses are also fed back to the system synchronizing generator where they actuate the low frequency counter which generates the frame deflection voltage.

A third mode of operation, which requires direct drive from the synchronizing generator, employes a technique known as resampling. This is simply the reverse of the technique used to generate the slow scan signal from a high speed image in the first place and involves first the deflection of the kinescope beam at a 15 kilocycle rate, rather than the very slow rate as was the case of the previous two modes of operation, and secondly superimposition of the sample pulses on the low speed video in order to generate a virtual very narrow line of information which may be slowly moved across the raster. This technique has several advantages: First in that some what improved stability can presumably be obtained by useage of a 15 kilocycle sweep rather than the very low frequency sweep. Second, that close correspondence between the resampling pulse and the original sampling pulse may be obtained thus reducing possible scan ambiguities. Third, and probably most important, the resampling process allows exotic sampling techniques to be performed on the original analog signal such as the use of two or more samples per television line, simulated diagonal scanning random scanning, or other methods which are outside of the scope of this discussion.

An optional piece of equipment which may be used with any of the aforementioned scanning modes is a spot wobble generator whose function is to increase the apparent width of the TV scanning line when very coarse pictures are under investigation, such as a picture containing only 128 scanning lines. The spot wobbler is simply a conventional sinewave oscillator with impedance matching circuits which drive a small deflection coil around the neck of the CRT tube. The frequency of operation is chosen as not to interfere with the functioning of any of the other system elements and the amplitude of the deflection voltage is adjusted to widen the scanning line to the point that a noticeable black area does not occur between adjacent lines.

To meet the resolution requirements of the system, a special transcribing type kinescope such as the Raytheon Type 5CEP11 is required. This tube is capable of resolving over 2,000 television lines and can be supplied with a P11 phosphor which is desirable both from the standpoint of resolution capabilities, freedom from grain, and also from the strong light output in the blue region, thus providing good recording sensitivity with standard photographic emulsions. Similarly, the short persistance characteristic of this phosphor makes possible convenient monitoring of the light output of the tube by means of a photoelectric cell. The physical size of the CRT also allows for convenient rack mounting, and the use of the flexible C12 Tektronix scope camera for the recording of the images produced.

Section 5

5.1 Synchronization Equipment

5.1.1

Figure 16 is a block diagram of the test facility synchronizing generator which provides not only timing pulses but test signals and deflection voltages as well. The basic timing for the entire system is derived from a 15 kilocycle oscillator or alternately from an external input which may be $\pm$ 10 per cent of this frequency. Two forms of operation are shown for the basic high frequency system synchronization pulse generation. The first of these is digital in nature, and by using a series of dividers a specific number of lines per TV frame may be selected ranging from 128 to 1536. A digital, vertical blanking signal is also available and may be selected to eliminate either 16, 32, or 64 horizontal lines from the number of active picture elements. A binary counter is used for this purpose and set so that the count starts with the initiation of the vertical drive pulse and ceases once a full count has been completed.

To improve flexibility, a second or nondigital timing mode is available in which an external frequency source of from 10 to 200 cycles per second may be used to generate the vertical drive signal. A coincidence circuit is used to time this external signal to the local or externally generated 15 kilo-cycle horizontal pulse, thus preventing ambiguity in the active picture area of repeated scans. Additional circuitry may be included, if so desired, after the output of the timer in order to generate interlaced signals.

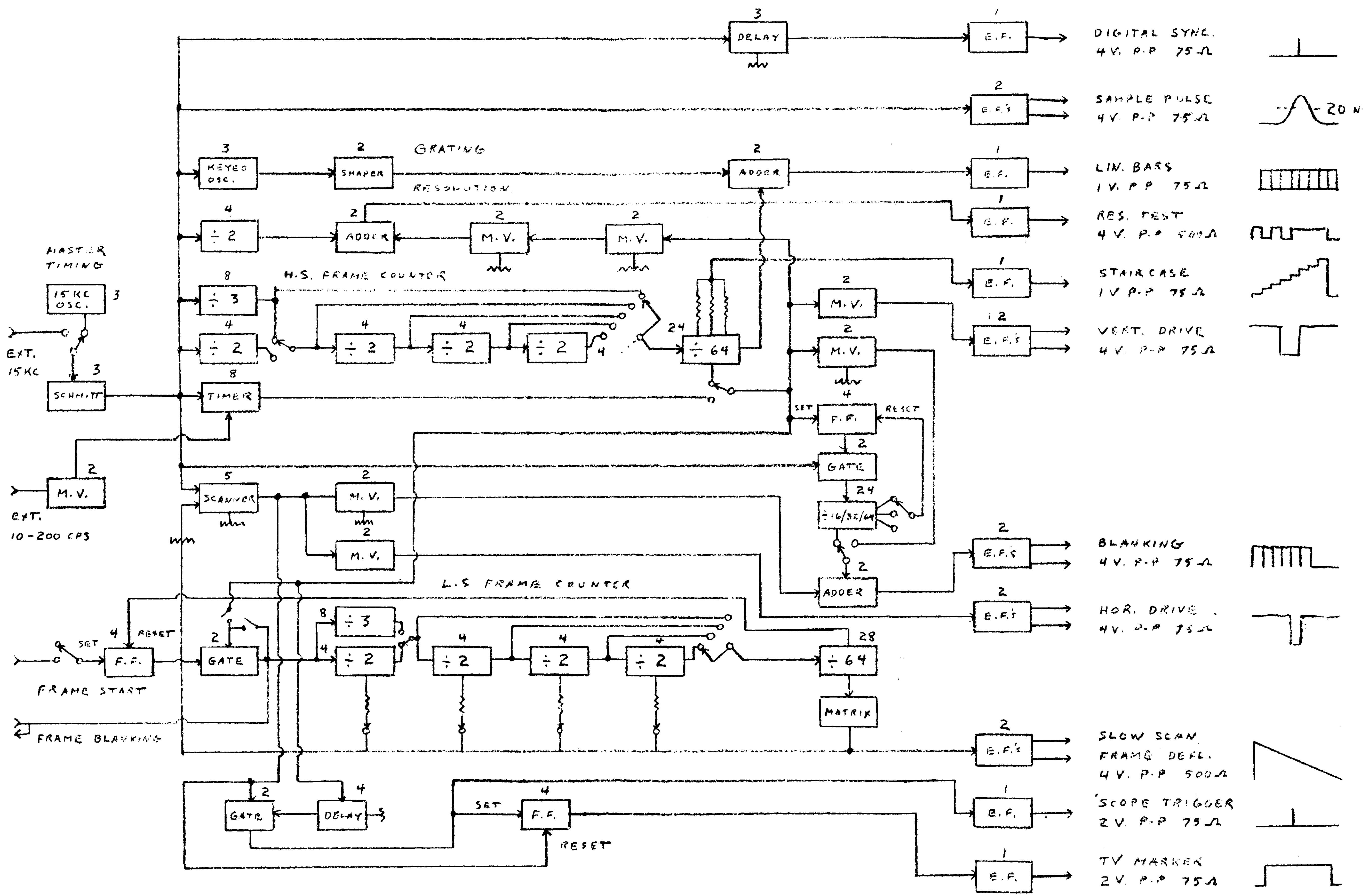


FIG 16, Slow-Scan Television Sync Generator

In the case of generation of either digital or analog vertical rate signals. the leading edge of the pulse is used to drive a delay multivibrator for the formation of the final vertical drive signal and the final vertical blanking component although, as previously noted, digital vertical blanking may be used as an option. The vertical drive pulse is essentially fixed in width at approximately 500 microseconds, while the analog vertical blanking pulse may be adjusted over a range of from less than 10 per cent to 50 per cent of the vertical scan time. In either mode of operation the horizontal blanking component is strictly of analog nature but again may be adjusted from less than 10 per cent to 50 per cent of the horizontal scan timing. The horizontal drive pulse is essentially fixed at a 5 microsecond value.

The sample pulse for the electronic scan converter is derived directly from the initial horizontal pulse generator and is indicated as being approximately 20 nanoseconds wide at the half amplitude point, thus allowing recovery of 25 megacycle components in the high speed video. A unique feature of this system is that the sample pulse remains fixed in time while the horizontal drive and the horizontal blanking signals are shifted in phase to generate the scanning action, thus producing an output signal format which is much more consistent with digital processing techniques. The scanning action takes place as is discussed in the early part of this report however the very low frequency sawtooth waveform is generated by means of a special counter, which again is capable of dividing in increments from 128 to 1536 The counter accepts vertical drive pulses through a gate and during the process of the countdown generates a staircase voltage signal by means of matrixing resistors. At the end of the count the gate is automatically shut off to prevent unwanted rescanning. The output of the gate also acts as a means of providing frame blanking for the slow scan TV monitor. Alternately the gate may accept drive signals from the TV monitor for the useage of the counter in generating sweep voltages with tape recorded television material.

The staircase waveform generated by the slow speed counter is applied directly to the sweep amplifier circuits in the slow scan monitor and also to the scanner in the sync generator. Two adjustments relating to the scanner are the setting of the desired starting point in the analog information, and secondly, a sweep width control to adjust the area on the high speed TV raster which will be covered by the scanning process. An analog method of generating a sawtooth to actuate the scanner is not shown because of the advantages of reproducibility and accuracy of setup obtainable with the previously discussed digital system.

5.1.2

Timing information from the basic 15 kilocycle oscillator, for use with external equipment such as analog-to-digital converters, is obtained through circuitry which allows adjustable delay, as shown at the very top of the block diagram. In addition, two isolated outputs are available for most of the pulses generated by a synchronizing generator in order that they may be used by peripheral equipment.

Section 6

6.1 Checkout Equipment

6.1.1

Incorporated in the synchronizing generator are means of generating several test signals. The first of these is a linearity bar generator in order to assist in the adjustment of aspect ratio and geometric linearity of the TV system. In essence, timed pulses are generated at both the vertical and horizontal high speed rate and may subsequently be superimposed over the image obtained from the high speed camera as shown in Figure 17. This illustration shows a standard RTMA 525 line grating pattern superimposed over a standard "ball" test chart. Ideally the intersections of the grating pattern should occur in the center of each of the circles, and due to the accurate electrical timing of the grating pattern, camera adjustments may be made to accomplish this without need to have performed very careful prior adjustments on the TV monitor.

A 16 by 16 bar grating pattern is anticipated, with the horizontal bars being generated by part of the digital countdown circuitry, and the vertical bars being produced by means of a keyed oscillator triggered by the horizontal drive. The grating generator may also be used to check out monitor linearity in the case of the high speed unit and also in the slow scan monitor when the high frequency sweep is employed and is a simple and stable reference for analysis of system linearity and aspect ratio characteristics.

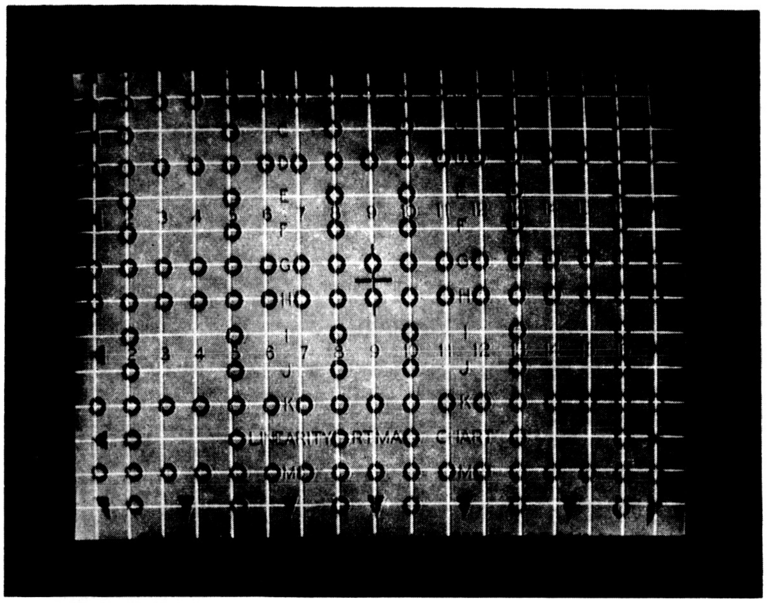


FIG 17, Standard TV Raster Showing Grating Signal Superimposed Over "Ball" Test Pattern

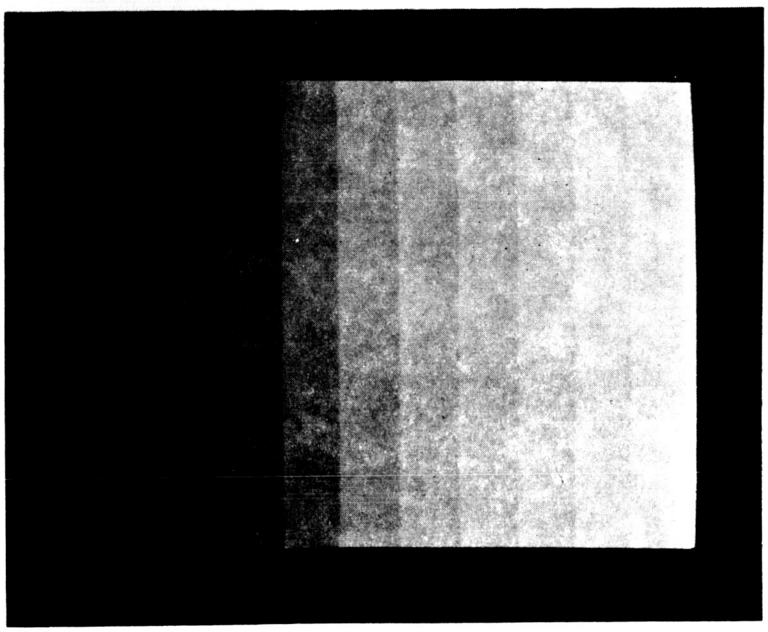


FIG 18, Standard TV Raster Showing Grey Scale Generated by Stairstep Signal

6.1.2

The amplitude transfer or "grey scale" characteristics of the system is of considerable importance and, consequently a staircase electrical waveform generator is included in the synchronizing generator block diagram. This may be readily achieved by adding matrixing resistors to the final section of the vertical countdown flip flops in the synchronizing generator. The generation of eight steps is indicated, primarily from the standpoint of convenience in making photometric or densitometric measurements on the final hard copy. Figure 18 is a photograph from the screen of a television monitor showing a standard grey scale of 12 steps. It will be noted that in the case of video test facility that horizontal steps, rather than vertical steps as shown, will be generated. This is in order to be consistent with the final low speed readout of the system and to allow individual checkout of the slow scan monitor. It may also be used in conjunction with the split screen generator to incorporate a fixed grey scale reference in the output signal from the electronic scan converter.

6.1.3

A third test signal included in the synchronizing generator block diagram is intended primarily for an objective means of analyzing the resolving power and adjusting the focus of the slow scan monitor tube. In this case a 7500 cycle squarewave is generated by means of a flip flop triggered by the basic 15 kilocycle pulse. This signal when applied to the input of the slow scan monitor, will be seen by the photocell as an A.C. component, the amplitude of which will vary depending upon the focus or resolving power of the CRT tube. To aid in the analysis a reference signal of relatively low frequency is generated by means of two multivibrators timed by the vertical drive pulse. This pulse is also a squarewave, but its width and also its position on the TV screen may be substantially varied and allows a direct indication of whether possible dropoff in response at edges of the TV raster is due either to failure of the photocell to pick up as much light or due to actual edge defocusing problems.

6.1.4

An investigation of various types of photographic equipment indicates that the Tektronix Type C12 oscilloscope camera should be ideal for the purpose intended. The C12 has its own light proof enclosure, is available with a variety of lenses, and is conveniently mounted to the front of the slow scan monitor. Of particular interest is the versatility of the camera back which will accept either the polaroid assembly for rapid checks of experimental work or standard 4 x 5 cut film backs which may be loaded with any of the normal black and white or color films for a permanent recording of experiments.

Section 7

7.1 Summary

The essential design recommendations for the construction of a video modulation test facility have been contained in the body of this report and little remains to be said other than generalities such as the useage of good commercial practice in terms of layout, accessibility of components, test points, ease of maintenance, etc. A standard rack mount configuration is assumed as is solid state circuitry where ever practical. Similarly, standard digital building blocks are anticipated for incorporation in the synchronizing generator circuits. One point still open to discussion, however, is the useage of printed circuit boards or whether hand wired circuitry would be desirable from the standpoint of possible future modifications to meet experimental needs.

A detailed list of equipment is incorporated in the appendix of this report as are recommended system interface and performance specifications. Procedures for the checkout and operation of the test facility are also included in this section.

It is considered by the writer that the results of this study were wholly encouraging and strongly support the practicality of a greatly improved, "state of the art," slow scan video test facility. Laboratory implementation of the philosophies discussed has already been made by adapting commercial medium resolution equipment as is shown in Figure 19. Although slight linearity discrepancies exist due to the experimental nature of the setup, the usefulness of this equipment can be seen in Figure 20, which is the slow scan signal encoded by means of delta modulation at a ratio of approximately 3 bits per sample and 16 quantizing levels.

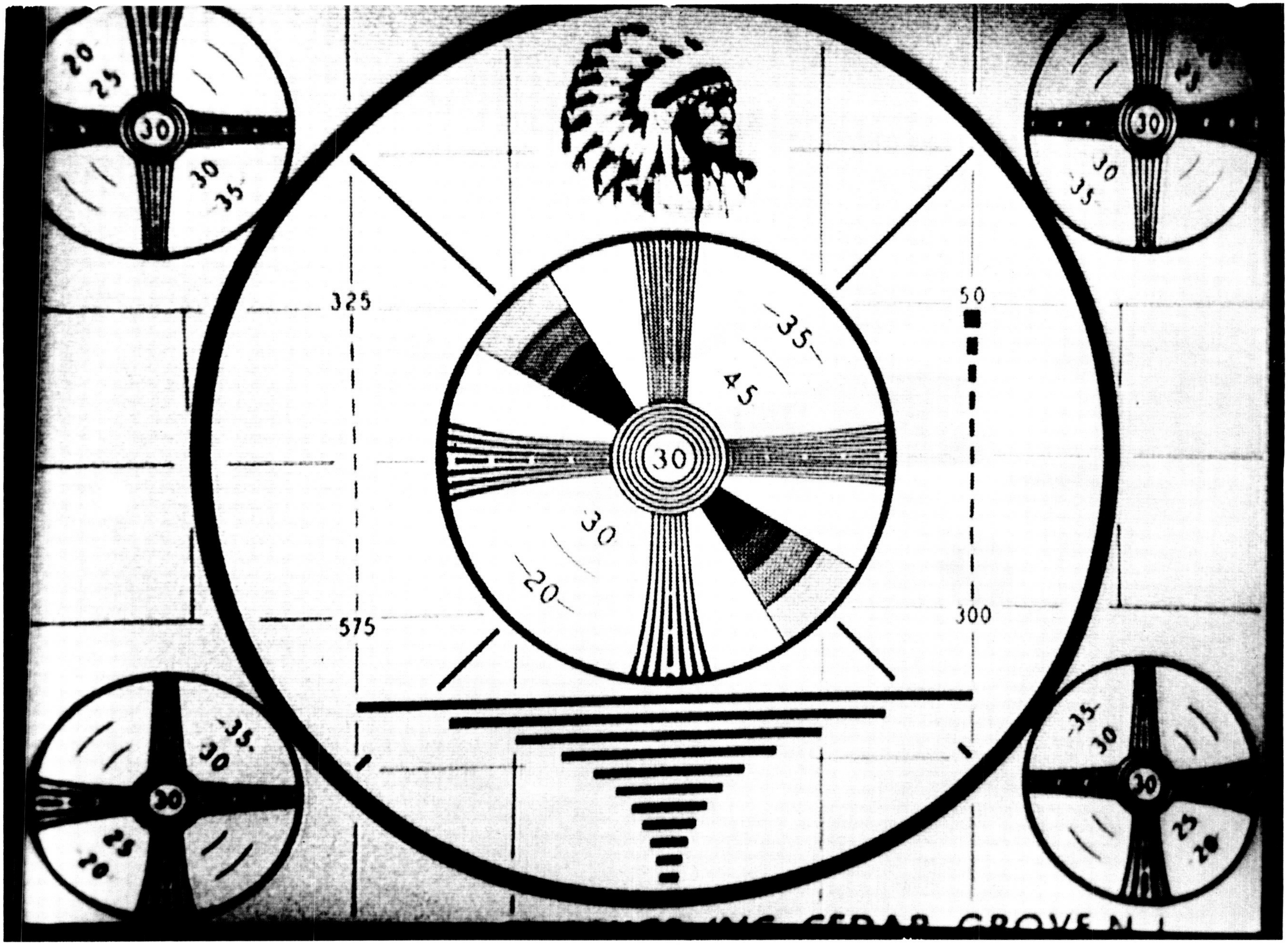


FIG 19, Experimental 500 Line Slow Scan Picture

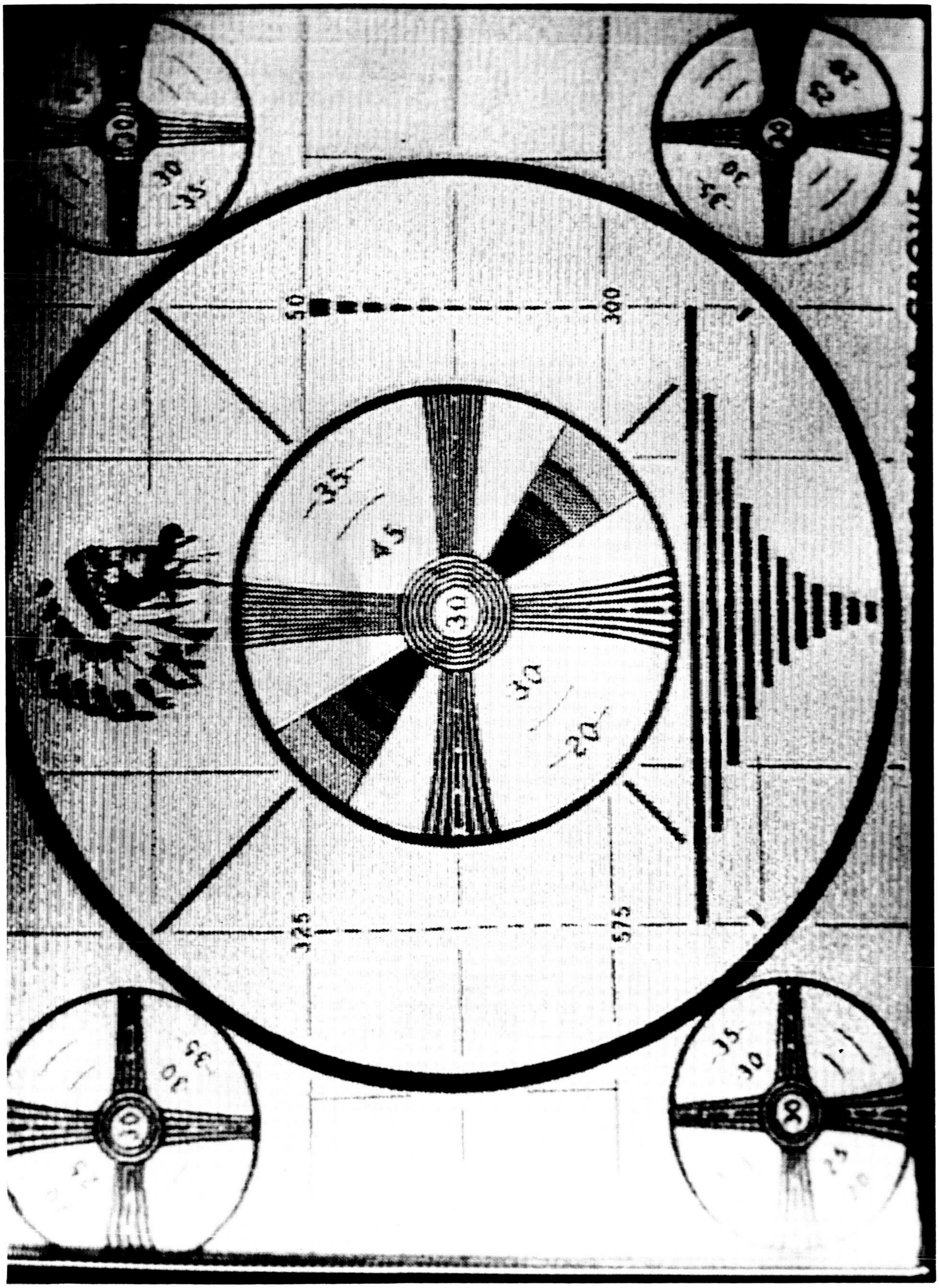


FIG 20, Signal of FIG 19 Encoded by Means of Delta Modulation

VIDEO TEST FACILITY

1. Equipment List

   a. Camera Head (BBRC)

      1. Camera head
      2. Two (2) 8051 vidicons
      3. 50 mm focal length lens, RCA MI-26550-1
      4. 90 mm focal length lens, RCA MI-26550-2
      5. 20' camera cable
      6. 42" copy stand

   b. Camera Sweep Chassis (BBRC)

   c. Camera Video Chassis (BBRC)

   d. System Synchronizing Generator (BBRC)

   e. Split Screen Generator (BBRC)

   f. Real Time Monitor (CONRAC CQB14/R with vertical deflection modification)

   g. Slow-Scan Monitor (BBRC)

      1. Two (2) 5CEP11 kinescope tubes
      2. TEKTRONIX C-12 scope camera
      3. SPELLMAN RG-30 regulated high voltage power supply

   h. Power Supplies, Low Voltage

      1. Three (3) LAMBDA LT-2095M
      2. One (1) LAMBDA 28M

   i. Racks (2) Standard JPL

   j. Rack Mount Oscilloscope, 5", 20 mc Bandwidth (TEKTRONIX)

   k. Operations Manual Including Complete Schematics (BBRC)

   l. Test Charts

1. Resolution
2. Geometric Linearity
3. Amplitude Linearity

2. Equipment Specifications

A. Camera

1. Inputs

a. Vertical Drive - 4 volts p-p, 75 ohms, 500 us negative pulse, 10-200 pps

b. Horizontal Drive - 4 volts p-p, 75 ohms, 5 us negative pulse, 15,000 pps

c. Blanking - 4 volts p-p, 75 ohms, negative going composite signal as determined by sync generator setting

d. Optical - 100 foot candles or better scene illumination

e. Sample Pulse - 4 volts p-p, 75 ohms, positive pulse 20 nanosecond width at half amplitude

2. Outputs

a. Wide Band Video - 1 volt p-p, 75 ohms, black negative,
2 outputs $\pm$ 2 db 10 cps - 20 megacycles

b. Low Band Video - 4 volts p-p, 500 ohms, black negative,
2 outputs $\pm$ 2 db DC - 7 kilocycles

3. Performance Characteristics

a. Scan linearity - Deflection current sawtooth linearity of 2 per cent on either axis

b. Flatness of field - Adjustable by means of parabolic waveforms in dynamic focus circuitry, nominally better than 10 per cent of useable contrast range

c. Resolution - Better than 10 per cent amplitude response at 1,000 lines at center of a 1 x 1 aspect ratio raster

d. S/N ratio - Better than 36 db when system is adjusted to resolve 500 TV lines with 50 per cent detail contrast

e. Amplitude linearity - Variable from .65 (8051 characteristic) to 1.3 by means of gamma correction circuitry

f. Color response - S-18

4. Operating Controls

a. Gain

b. Black Level

c. Beam Current

d. Beam Focus

e. Gamma

f. Target Voltage

g. Aperture Correction

h. Video Preset

i. Horizontal Size

j. Horizontal Centering

k. Vertical Size

l. Vertical Centering

m. High Frequency Equalization

n. Low Frequency Equalization

o. Horizontal Dynamic Focus

p. Vertical Dynamic Focus

B. Synchronizing Generator

1. Outputs

   a. Horizontal Drive - 4 volts p-p, 75 ohms, 5 us negative pulse, 15,000 pps

   b. Vertical Drive - 4 volts p-p, 75 ohms, 500 us negative pulse, 10-200 pps

   c. Blanking - 4 volts p-p, 75 ohms, negative signal

   d. Slow-Scan Frame Signal - 4 volts p-p, 500 ohms, ramp signal

   e. Sample Pulse - 4 volts p-p, 75 ohms, positive pulse, 20 ns width, 15,000 pps

   f. Grey Scale Staircase - 1 volt p-p, 75 ohms, 8 steps at multiple of system frame rate

   g. Linearity Test Signal - 1 volt p-p, 75 ohms, white positive signal producing 16 vertical bars and 16 horizontal bars

   h. Resolution Test Signal - 1 volt p-p, 75 ohms, 7,500 cycle square wave, variable width and position reference pulse

   i. Digital Sync - 4 volts p-p, 75 ohms, 15,000 pps

   j. Scope Trigger - 2 volts p-p, 75 ohms

   k. Scope Marker - 2 volts p-p, 75 ohms

2. Inputs

   a. External Line Frequency - 4 volts p-p, 75 ohms, 15,000 pps $\pm$ 10 per cent

   b. External Frame Frequency - 4 volts p-p, 75 ohms, 10-200 pps

3. Operating Controls

   a. Internal/External Line Rate

b. Internal/External Frame Rate

c. Lines/Frame Selector, 128, 192, 256, 384, 512, 768, 1024, 1536

d. Samples/Line, 128, 192, 256, 384, 512, 768, 1024, 1536

e. Horizontal Blanking Width

f. Digital/Analog Vertical Blanking

g. Digital Blanking Width, 16, 32, 64 lines

h. Analog Vertical Blanking Width

i. Sampling Static Position

j. Sampling End Limits

k. Resolution Test Reference Pulse Position

l. Internal/External Frame Start

m. Digital Sync Delay

n. Scope Trigger Delay

C. High Speed Monitor

1. Inputs

   a. Vertical Drive - 4 volts p-p, 75ohms, 500 us negative pulse, 10-200 pps

   b. Horizontal Drive - 4 volts p-p, 75 ohms, 5 us negative pulse, 15,000 pps

   c. Video - 1 volt p-p, 75 ohms, black negative

Monitor to be CONRAC Type CQB14/R with 14ABP19 kinescope tube or alternately 14ABP7 kinescope tube to minimize flicker. Vertical sweep circuits to be replaced with wide range transistorized unit to accommodate various scan rates.

D. Low Speed Monitor

1. Inputs

   a. Vertical Drive - 4 volts p-p, 75 ohms, 500 us negative pulse, 10-200 pps

   b. Frame Signal - low frequency ramp, 4 volts p-p, 500 ohms

   c. Horizontal Drive - 4 volts p-p, 75 ohms, 5 us negative pulse, 15,000 pps

   d. Low Speed Frame Blanking Signal - gated vertical drive pulses

   e. Video - 1-4 volts p-p, 500 ohms, black negative (50 kc bandwidth)

   f. Sample Pulse - 4 volts p-p, 75 ohms, 20 ns width, positive pulse, 15,000 pps

2. Outputs

   a. Counter Start Signal

   b. P. E. Cell Monitor Signal

3. Performance Characteristics

   a. Scan Linearity - Deflection current sawtooth linearity of 5 per cent on either axis

   b. Flatness of Field - Dependent upon CRT characteristics

   c. Resolution - 1,500 TV lines with square raster format

   d. S/N Ratio - 40 db or better at CRT grid

   e. Amplitude Linearity - Electrical: Better than 5 per cent at 30 volts drive to CRT grid. Optical: Dependent upon CRT characteristics

   f. Color Response - Peak output at 4,600 angstroms (blue) with a P11, short persistence, phosphor.

4. Operating Controls

a. Video Level

b. Brightness

c. Focus

d. Spot Wobble

e. Sampling Pulse Amplitude

f. Sync Separator Level

g. H. Amplitude

h. V. Amplitude

i. H. Centering

j. V. Centering

k. Internal/External Sweeps

l. Sampling on/off

m. Low Frequency Sweep Setup

3. Operational and Test Procedures

A. Synchronizing Generator

This unit should be the first to be turned on as it supplies signals essential to the operation of the other units. No setup adjustments are anticipated and the operating controls are primarily for the alteration of significant parameters of interest to the experimenter. Typically master timing is derived from the local 15 kilocycle oscillator and the vertical drive pulse timing obtained from the digital countdown circuit set to a count of 1,024. Vertical blanking may be set digitally at 64 lines, and the horizontal blanking width set to approximately 10 microseconds. Further operations in this area will be discussed in the following sections.

B. Fast Scan Monitor

This unit should be turned on second in sequence and the brightness control adjusted so that a blank raster appears on the face of the picture tube thus indicating the proper operation of the synchronizing generator. Following this, the contrast should be advanced in order to monitor the output of the camera system.

C. Television Camera

Third in the sequence of operations, time should be allowed for the warmup of the vidicon and the preamplifier tubes. Black level and video gain controls should be advanced until a small amount of noise appears on the face of the high speed monitor thus assuring that the video channel is operating properly.

Following this, the subject in front of the camera lens, preferrably a test pattern, may be illuminated and the camera beam current turned up until a picture appears on the high speed monitor. Optical and electrical focusing may be done at this time as well as any of the adjustments relating to the proper scanning of the face of the vidicon tube such as horizontal and vertical sweep size and centering.

Precise electrical setup of the camera may now be accomplished by means of an oscilloscope. In most instances, the examination of the waveforms at the output of the slow scan conversion unit will be satisfactory for the proper adjustment of black level, video amplitude, and gamma transfer characteristics of the camera. Vertical focusing may also be accomplished by "looking" at the particular part of a test pattern containing fine resolution wedges as indicated in Figure 9 of the text. A section of the test pattern producing an oscilloscope trace similar to that shown in Figure 12c should be selected and both optical and electrical focus adjusted for maximum amplitude. Electrical focus should be checked periodically as this is one area where slight drifts are difficult to eliminate. If the reproduction of color subjects is being investigated, the spectral response characteristics of the light source and the camera may be checked out by illuminating a black and white subject and interposing tri-color separation filters between the lens and the subject as indicated in Figure 4 of the text.

Dynamic focus voltages will presumably remain fixed in the case of the horizontal component as the speed of the sweep remains at 15 kilocycles. In the case of the vertical compensation component, some adjustment in amplitude may be desirable when frame rates are varied. In this case the output of the slow scan converter may be viewed on an oscilloscope and adjustments of the vertical parabola voltage made for best flatness of field and maximum corner resolution.

A change in the input capacitance of the video preamplifier, such as might occur when changing the preamp or vidicon tube, may require some readjustment of the high frequency equalization circuit. This may frequently be done by looking at the high speed monitor and adjusting equalization so that neither black nor white smear occurs after rapid transitions from black to white in a test pattern. More precisely, the oscilloscope may be used with the triggered sweep circuit and set to examine only one line of the horizontal TV information as shown in Figure 10. Again a sharp transition from black to white is sought out and high frequency equalization adjusted for minimum undershoot or over shoot. If the vidicon tube itself is changed, some readjustments in target voltage, size, centering, dynamic focus, and alignment voltages may be required.

Additional operational variations may be obtained by adjusting the aperture correction circuit in the high frequency channel of the TV camera for improved detail response although this lowers the overall signal-to-noise ratio of the system. The high frequency signal may also be filtered or otherwise operated on between the output of the camera and the input to the slow scan converter. Again provision is made for the insertion of an interpolation filter or other devices between the output of the converter and the inputs of the operational amplifiers used for signal distribution.

D. Slow Scan Monitor

This is normally the last unit to be turned on, and appropriate time for tube warmup should be allowed before high voltage is applied to the kinescope tube. Attention should be paid at this time to ensure that some malfunction does not cause excessive screen brightness or failure of sweep or blanking circuitry which might cause repeated scanning of a small area of the phosphor. No light output should appear from the screen until the blanking multivibrator is triggered, which may be accomplished either by initiating a sweep or by closing the override switch in the sync generator. The latter is desirable for setup purposes as it allows a stationary line to appear on the screen, positioning of which depends upon the adjustment of the centering controls although normally it will appear at the very left hand side of the screen. Only a very faint line should be visible even though the blanking multivibrator is triggered. Adjustments of centering and size controls may be made at this time.

Focusing of the CRT may be done by visual inspection of the screen, however, a preferred technique, which allows objective evaluation, is to use the resolution test signal generated in the synchronizing generator. The system oscilloscope is then connected to the output of the photocell monitoring the light output of the tube, and the focus control adjusted for maximum amplitude of the high frequency square wave signal. If necessary, this test may be repeated in several parts of the screen to analyze the uniformity of focus.

Brightness and contrast adjustments may next be made with either video information or the staircase signal feeding into the input of the monitor. Again the output of the photoelectric cell is displayed on the system oscilloscope in order to determine the desired range of brightness. Monitor gamma adjustments may also be made at this time.

When the resampling technique is used, the major readjustments required are the changing of the horizontal sweep from the very low frequency sawtooth source to the 15 kc sweep rate of the high speed camera and the reduction in the kinescope brightness level to the point at which video information would normally be invisible. Sampling pulses are then added to the video and adjusted in amplitude until appropriate brightness and grey scale response is achieved.

The slow scan frame time is set by adjustment of the very low frequency counter in the synchronizing generator, while frame centering and width are adjusted by first positioning the sampling line marker at the left hand edge of the picture information as viewed on the high speed monitor, while at the same time the low speed monitor beam is positioned to the left hand side of the CRT. The scanner is then switched to a reference voltage equal to the counter end limit and both the scanner and slow scan monitor sweep amplitude adjusted to the proper width by observation of the respective screens.

Following these procedures, slow scan pictures may be reproduced by opening the lens shutter of the C-12 film camera and triggering the very low frequency frame counter. An initial series of tests should be made with the grey scale test signal and the types of film to be used. The cooperation of the photo lab should be enlisted to analyze the developed negatives for optimum screen brightness and camera lens settings. The film processing and printing techniques should also be standardized in order to obtain consistent results in future experiments.